A Cool Way to Boil Water

Evaporation and Boiling

Introduction

The boiling point of water is directly affected by vapor pressure.

Concepts

- Boiling point

Materials

Filter flask, 250-mL
Hot plate
Ice
Rubber tubing, flexible, 8-cm piece to fit sidearm of flask
Screw clamp
Solid stopper, #6, to fit flask
Utility clamp

Safety Precautions

Follow all laboratory safety guidelines. Use only Pyrex® flasks and carefully check the flask before use for cracks, scratches, or any damage. Since the flask will be under vacuum, it must be in perfect condition. Wear chemical splash goggles at all times when working with chemicals, glassware or heat in the laboratory. Wear heat-resistant gloves and use caution when working with the hot flask to avoid scalding or burns. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

1. Attach an approximately 8-cm piece of flexible rubber tubing to the side arm of a 250-mL filter flask. Place a screw clamp on the rubber tubing, leaving the screw clamp loosened.
2. Fill the 250-mL filter flask about one-third full of distilled water.
3. Attach a utility clamp to the flask, and then attach the flask to a ring stand, while positioning it on top of a hot plate.
4. Heat to the water in the filter flask to boiling, and then continue to heat until about half of the original amount of water remains.
5. Remove the heat source, and wait for the boiling to cease. Then stopper the flask and tighten the screw clamp to seal the system. The stopper and screw clamp must be tight! Refer to the diagram.
6. Detach the flask from the ring stand. Carefully invert the flask (using a cloth if necessary), and reattach the inverted flask to the ring stand.
7. Place ice on the bottom of the filter flask repeatedly to cool the flask. (It is suggested that you place a container underneath the flask to collect water from the melted ice.) The water will begin to boil again!
8. As you continue to add ice, the water will continue to boil.
9. When the boiling has ceased (or when you choose), place the flask upright and open the screw clamp and/or remove the stopper. A “whoosh” sound occurs due to the pressure change.

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Disposal

Please consult your current Flinn Scientific Catalog/Reference Manual for general guidelines on specific procedures governing the disposal of laboratory waste. All chemicals used in this demonstration may be disposed of down the drain according to Flinn Suggested Disposal Method #26b.

Tips

- A connection can be made between the effect of atmospheric pressure on the boiling point of water and the adventures of the Martian rover. You may precede the demonstration by reading a short story from the NASA Web site, "To Distill Some Water," which is patterned after the Jack London 1908 short story "To Build a Fire." The first sentence of this Jack London classic reads,

  "*Day had broken cold and gray, exceedingly cold and gray, when the man turned aside from the main Yukon trail and climbed the high earth-bank, where a dim and little-traveled trail led eastward through the fat spruce timberland.*"

  Ask students if they recognize the author and the title of the story. (Virtually all students will have read the story, and some will have even seen a video.) Then discuss the setting of the story. This leads to the setting for "To Distill Some Water."

  "To Distill Some Water" begins:

  "Day had broken, cold and reddish, exceedingly cold and reddish from dust suspended in Mars's thin atmosphere, when the explorer climbed the inner crater wall."

  Later in the story, the explorer attempts to remove distilled water from an oven:

  "He unlocked the oven's external door, retrieved the cup, and moved to drain it into his suit's water bottle. But not fast enough. The water began fizzing and steaming angrily, leaping over the rim and then freezing in a tiny cloud of ice crystals. In moments, the cup was completely dry.

  He struggled for calm. Liquid water was highly unstable in Mars's vacuum-like atmosphere. He knew that, but he didn't realize how rapid it would boil."

  After reading the story, perform the demonstration. After the demonstration, the class engages in a modified version of the activity, "Life on Planet V," from *The Gas Laws*, one of the *Flinn ChemTopic™ Labs*.

  This activity asks the question, "What would it be like to live in a vacuum? Which of our tools and toys would still work the same? better? not at all?"

  Here is a partial list of the items: suction cup, candle, flashlight, plant, air bag, star, magnet

- Here is an excerpt from the referenced Flinn ChemTopic™ activity—

Life on Planet V
A Classroom Activity

Overview of the Activity

Discuss the fact that there is no such thing as suction—things do not get pulled or sucked by a vacuum, but instead they get pushed from the other side by atmospheric pressure. After performing a classic pressure vs. vacuum demonstration such as "The Collapsing Can," use this "mental lab" activity to stimulate further discussion and understanding of this concept. The debates that result are sure to lead to some of the best learning of the year!

Procedure

Imagine you have been relocated to Planet V, a planet just like Earth, but with no atmosphere at all. Which of the items listed below would still work on this planet and which items would not work? For those items that would work, would they work exactly the same? For those items that would not work, can you think of modifications that would enable them to work? Be prepared to defend your answers!

Discussion

There are no clear-cut, yes or no answers for many of the items. The purpose is not to get the right answer, but to get students thinking about the role that the atmospheric pressure plays in everyday life.

Suction cup: No, since there's no pressure to push it against the wall, it wouldn't stick.
Candle: No, since combustion requires oxygen.
Flashlight: Yes, light does not require air.
Plant: No. Obviously with no air there would be no carbon dioxide available for photosynthesis.
Air bag: Yes. A quick gas-producing chemical reaction inflates them.
Star: Yes, of course. Stars already work just fine in the vacuum where they exist. Like fission, fusion does not need oxygen. This is a good opportunity to point out that stars are not burning the way a candle does.
Magnets: No problem here.

In Volume 9 of the *Flinn ChemTopic Labs* book there are 30+ more examples.

Sources
A copy of "To Build A Fire" can be found at: www.pagebypagebooks.com
A copy of "To Distill Some Water" can be found by searching for the story by title, or at:
http://science.nasa.gov/headlines/y2002/09aug_marstale.htm

Discussion

When the water in the flask boils, water vapor forces the air out of the flask. When the flask is "sealed," the gas above the liquid water is essentially water vapor. When the water vapor is cooled by placing ice on the flask, the water vapor condenses, and the pressure in the flask is significantly lowered. This allows the water to boil at a lower temperature, as boiling of water occurs when the vapor pressure of the water molecules within the liquid equals the external pressure.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Form and function
Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, motions and forces
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, motions and forces

Reference

Demonstration originally performed by John Hnatow, Jr., Emmaus High School, Emmaus, Pennsylvania.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *A Cool Way to Boil Water* activity, presented by Kathleen Dombrink, is available in *Evaporation and Boiling*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *A Cool Way to Boil Water* are available from Flinn Scientific, Inc.

Catalog No.	Description
GP4072	Flask, Filtering, Borosilicate Glass, Pyrex®, 250 mL
AP7234	Hot Plate, Flinn 7″ × 7″
AP8214	Hoffman-Type Clamp
AP1034	Single Buret Clamp, Plastic, Coated Jaw
AP2078	Latex Tubing
AP6367	Flinn ChemTopic™ Labs, Vol. 9, The Gas Laws

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.